February 2015

Impact and correlation of environmental conditions on pollen counts in Karachi, Pakistan.

Anjum Perveen
University of Karachi, Karachi,, dranjumperveen@gmail.com

Muneeba Khan
University of Karachi, Karachi,, muneeba1984@hotmail.com

Shaista Zeb
University of Karachi, Karachi,

Asif Ali Imam
Aga Khan University

ORIGINAL ARTICLE
Iran J Allergy Asthma Immunol
February 2015; 14(1):83-90.

Impact and Correlation of Environmental Conditions on Pollen Counts in Karachi, Pakistan

Anjum Perveen[1], Muneeba Khan[1], Shaista Zeb[2], and Asif Imam[3]

[1] Centre for Plant Conservation, University of Karachi, Karachi, Pakistan
[2] Department of Botany, University of Karachi, Karachi, Pakistan
[3] Aga Khan University Hospital, Karachi Pakistan

Received: 12 November 2013; Received in revised form: 12 March 2014; Accepted: 8 April 2014

ABSTRACT

A quantitative and qualitative survey of airborne pollen was performed in the city of Karachi, and the pollen counts were correlated with different climatic conditions. The aim of the study was to determine the possible effect of meteorological factors on airborne pollen distribution in the atmosphere of Karachi city.

Pollen sampling was carried out by using Burkard spore Trap for the period of August 2009 to July 2010, and a total of 2,922 pollen grains/m^3 were recorded.

In this survey, 22 pollen types were recognized. The highest pollen count was contributed by Poaceae pollen type (1,242 pollen grains/m^3) followed by Amaranthaceae/Chenopodiaceae (948 pollen grains/m^3), *Cyperus rotundus* (195 pollen grains/m^3) and *Prosopis juliflora* (169 pollen grains/m^3). Peak pollen season was in August showing a total of 709 pollen grains/m^3 and lowest pollen count was observed in January-2010. Pearson's chi-square test was performed for the possible correlation of pollen counts and climatic factors. The test revealed significant positive correlation of wind speed with pollen types of Amaranthaceae/Chenopodiaceae; *Brassica campestris*; Asteraceae; and *Thuja orientalis*. While the correlation of "average temperature" showed significant positive value with Asteraceae and *Tamarix indica* pollen types. Negative correlation was observed between humidity/ precipitation and pollen types of *Brassica campestris*; *Daucus carota*; *Ephedra* sp.; and *Tamarix indica.*

In the light of above updated data one could identify various aeroallergens present in the air of Karachi city.

Keywords: Airborne; Allergic rhinitis; Conditions; Karachi; Pollen

INTRODUCTION

Airborne pollen grains are important aeroallergensthat may cause allergic rhinitis and asthma in human beings.[1,2] Various studies have evidenced the correlation between the high airborne pollen count and allergy symptoms in hypersensitive individuals.[3] Pollen grains that cause allergy are usually

Corresponding Author: Anjum Perveen, PhD;
Centre for Plant Conservation, University of Karachi, Karachi-75270, Pakistan. Tel: (+92 21) 9926 1369, E-mail: dranjumperveen@gmail.com

Published by Tehran University of Medical Sciences (http://ijaai.tums.ac.ir)

very small in size and can easily reach the lower respiratory tract.[4]

Airborne pollen data varies from place to place due to floristic diversities in a geographical region. This data helps to identify the types and count of air spora present in the atmosphere of the study area. Climatic conditions of an area may also aid in increasing the incidence of bronchial allergies as plant growth, dispersion, and quantity of pollen grains are directly correlated with weather conditions of the area.[5-7] Pollen calendar also aid in the appropriate diagnosis of the aeroallergens. Various aerobiological data and clinical records are being used for the treatment of allergic patients.[8-10]

Preliminary study of atmospheric pollen has been carried out by Kazmi, et al.[11] in Karachi, similarly Perveen, et al.[12] and Waqar et al.,[13] conducted aerobiological studies in Karachi and adjacent area in relation to allergy. No data base was available on airborne pollen grains in Karachi for the period of August 2009 to July 2010 in relation to environmental conditions. The aim of the present work is to establish an updated diurnal and seasonal frequency of airborne pollen grains and to correlate them with various climatic factors like average temperature, wind humidity, wind speed, clouds and precipitation.

MATERIALS AND METHODS

Study Site

Karachi is the largest as well as most populous city of Pakistan and the capital of Sindh province in Pakistan. It is the chief seaport of Sindh. The city is spread over 3,527 km^2 (1,362 sq miles) in area. Karachi is located in the south of the country on the coast of the Arabian Sea. Its geographic coordinates are 24°51′ N 67°02′ E. Karachi tends to have a warm, tropical and arid climate with low average precipitation levels approx. 250 mm (Waqar, et al., 2010a 13).

Vegetation

Vegetation of the Karachi city is similar to vegetation of dry regions. The flora of the city is mainly composed of trees, shrubs and herbaceous plants. The dominant trees are Acacia nilotica, Albizia lebbeck, Azadirachta indica, Bauhinia variegata, Callistemon citrinus, Cassia fistula, Delonix regia, Ficus benghalensis, Eucalyptus globulus, Guaiacum officinale, Leucaena leucocephala, Moringa oleifera, Peltophorum roxburghii, and Pithecellobium dulce**.** Common shrubs in the area are Bougainvillea glabra, Senna italica, Hibiscuss rosa-sinensis, Haloxylon persicum, Ixora coccinea, Nerium indicum, Ocimum basilicum, Parkinsonia aculeata, Prosopis juliflora, Ricinus communis, Rosa indica, Thespesia populnea, Typha angustata and Ziziphus numularia, etc. Herbaceous vegetation including grasses are Aerva javanica, Amaranthus viridis, Atriplex stocksii, Blepharis sindica, Cadaba fruticosa, Cenchrus biflorus, Cenchrus ciliaris, Chenopodium album, Chloris barbata, Cleome viscosa, Cressa cretica, Cynodon dactylon, Cyperus rotundus, Dactyloctenium scindicum, Dichanthium annulatum, Digera muricata, Iphiona grantioides, Plucia sp., Pulicaria sp., Peristrophe bicalyculata, phragmites karka, Salsola imbricata, and Tridax procumbens. Cultivated Poaceae members include Saccharum officinarum, Pennisetum glaucum, and Oryza sativa.

Pollen Count

A continuous sampling was carried out from August 2009-July2010 by using Burkard's 7-day volumetric spore trap, installed around 10 meters above ground level on the roof of the Center for Plant Conservation in the campus of University of Karachi. The data collecting drum was changed weekly. Permanent slides were prepared by using moviol and stained by basic fuchsin. Pollen grains were counted for each hour and all the counts for the whole day, weeks and months were summarized into average daily, monthly, and yearly pollen concentration/m^3 according to the guidelines of British Aerobiology Federation.[14] Pollen grains are identified by the help of reference slides prepared from local vegetation and literature surveys.[15,16]

Climatic Data

Meteorological data of one year (August 2009 to July 2010) including average temperature, wind humidity, wind speed, clouds and precipitation were provided by the weather station located in the city of Karachi. The relationship between the meteorological conditions and total pollen concentration was calculated. Pearson Chi-square test was performed by using SPSS software to determine the correlation of meteorological factors with pollen grains counts.

RESULTS

In this survey, a total of 2,922 pollen grains/m^3 and 22 pollen types were recorded (Table 1) namely.

Amaranthaceae/Chenopodiaceae, Azadirachta indica, Betula utilis, Brassica campestris, Capparidaceae, Asteraceae, Conocarpus erectus, Cyperus rotundus, Daucus carota, Delonix regia, Ephedra sp., Eucalyptus globulus, Poaceae, Guaicum officinale, Leucaena leucocephala, Moringa oleifera, Pinus roxburghii, Prosopis juliflora, Rumex crispus, Tamarix indica, Thuja orientalis Typha angustifolia. The unknown or damaged pollen grains were included in unidentified type. The highest concentration of pollen grains was detected in the month of August 2009 (Table 1) in which 709 pollen grains/m^3 were counted. The second highest peak of 613 pollen grains/m^3 was recorded in September 2009. The lowest pollen count was recorded in the month of January 2010 i.e. 59 pollen grains/m^3.

Poaceae pollen type showed the highest number of pollen grains i.e. 42.50% (1,242 pollen grains/m^3) (Table 1). The second highest pollen concentration was mainly due to Amaranthaceae/Chenopodiaceae with 32.44% (948 pollen grains/m^3). Other pollen grain counts were as following; Cyperus rotundus 6.67% (195 grains/m^3), Prosopis juliflora 5.78% (169 pollen grains/m^3), Typha angustifolia 2.089% (61 pollen grains/m^3), Brassica campestris 2.05% (60 pollen grains/m^3), Conocarpus erectus 1.71% (50 pollen grains/m^3), Guaicum officinale 1.129% (33 pollen grains/m^3), Tamarix indica 1.06% (31 pollen grains/m^3), Eucalyptus globulus 0.855% (25 pollen grains/m^3), Ephedra sp. 0.479% (14 pollen grains/m^3), Daucus carota 0.410% (12 pollen grains/m^3), Leucaena leucocephala 0.376% (11 pollen grains/m^3), and others having less than 10 pollen grains/m^3 count. The recorded pollen types with known allergenicity have been represented in Table 2.

Table 1. Monthly total pollen concentration of all pollen types in the atmosphere of Karachi during 2009-2010.

Name of Pollen types	Aug, 09	Sep, 09	Oct, 09	Nov, 09	Dec, 09	Jan, 10	Feb, 10	Mar, 10	Apr, 10	May, 10	June, 10	July, 10	Total
Amaranthaceae/Chenopodiaceae	286	232	222	44	16	11	23	30	25	18	10	30	948
Azadirachta indica	0	1	0	0	0	3	0	4	0	0	0	0	8
Betula utilis	0	0	1	0	0	0	0	0	0	0	0	0	1
Brassica campestris	11	3	3	9	0	0	8	3	13	5	1	4	60
Capparidaceae	6	0	0	0	0	0	0	0	0	0	0	0	6
Asteraceae	0	1	0	0	0	0	0	2	0	0	0	0	3
Conocarpus erectus	20	4	10	0	0	1	9	5	0	0	0	1	50
Cyperus rotundus	37	71	4	14	0	8	2	15	8	10	10	16	195
Daucus carota	0	0	0	0	0	0	3	0	6	0	3	0	12
Delonix regia	0	0	0	0	0	0	0	0	0	0	1	0	1
Ephedra sp.	0	0	5	0	0	0	2	0	6	0	1	0	14
Eucalyptus globulus	0	4	1	0	0	0	3	4	7	3	0	3	25
Poaceae	329	256	104	89	29	29	23	58	49	26	187	63	1242
Guaicum officinale	3	4	1	0	3	0	2	5	3	7	4	1	33
Leucaena leucocephala	0	0	0	0	1	0	6	0	3	0	1	0	11
Moringa oleifera	6	0	0	0	0	0	0	0	0	0	0	0	6
Pinus roxburghii	0	0	0	0	0	0	0	0	0	1	0	0	1
Prosopis juliflora	11	13	99	7	11	4	3	7	1	4	4	5	169
Rumex crispus	0	0	1	0	0	0	2	0	0	0	0	0	3
Tamarix indica	0	0	14	0	0	3	3	8	0	0	0	3	31
Thuja orientalis	0	0	3	0	0	0	2	0	1	0	3	0	9
Typha angustifolia	0	20	1	14	0	0	0	8	4	0	6	8	61
Unknown	0	4	1	0	0	0	9	5	1	7	1	5	33
Total	709	613	470	177	60	59	100	154	127	81	232	139	2922

Table 2. List of pollen types with known allergenicity

Pollen types	Percentage
Poaceae	42.51%
Amaranthaceae/Chenopodiaceae	32.44%
Cyperus rotundus	6.67%
Prosopis juliflora	5.78%
Brassica campestris	2.05%
Tamarix indica	1.06%
Eucalyptus globulus	0.86%
Thuja orientalis	0.31%
Azadirachta indica	0.27%
Moringa oleifera	0.21%
Betula utilis	0.03%

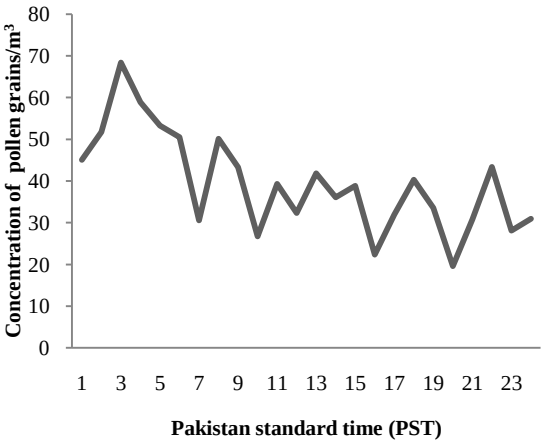

Figure 1. Diurnal pattern of Amaranthaceae/ Chenopodiaceae

Seasonal Variation

During the investigated period, airborne pollen grains were recorded all year round and reached at maximum level in August 2009, September 2009 and October 2009 (Table 1). The highest concentration of grass pollen (329 pollen grains/m^3) was recorded in the month of August-2009, and its lowest concentration (23 pollen grains/m^3) was recorded in the month of February-2010 (Table 1). Amaranthaceae/ Chenopodiaceae pollen grain pollen type was detected throughout the year, however, the highest concentration was noticed in the month of August 2009 (286 pollen grains/m^3). *Prosopis juliflora* pollen was also recorded throughout the year. Highest pollen count of *Brassica campestris* was detected the month of April while in October highest pollen count of *Conocarpus erectus*, *Tamarix indica*, and *Prosopis juliflora* was noticed. *Tamarix indica* blooming season is from January-October and our sampler also recorded the highest concentration of pollen grains of *Tamarix indica* in the month of October-2009. *Prosopis juliflora* blooming season is observed twice a year i.e. March- June, September-November and in our study its highest pollen grain concentration was recorded in the month of October-2009. *Eucalyptus globulus* also flowers from mid winter to mid summer and its pollen trapped during our study in almost similar months.

Diurnal Periodicities

Diurnal patterns of the most abundant pollen types were constructed (Figure 1-4). For this purpose, hourly data was studied for 24 hours each day for the whole month and study year. These pollen counts were then converted into average pollen count/m^3 for the study year. Then the diurnal patterns were constructed.

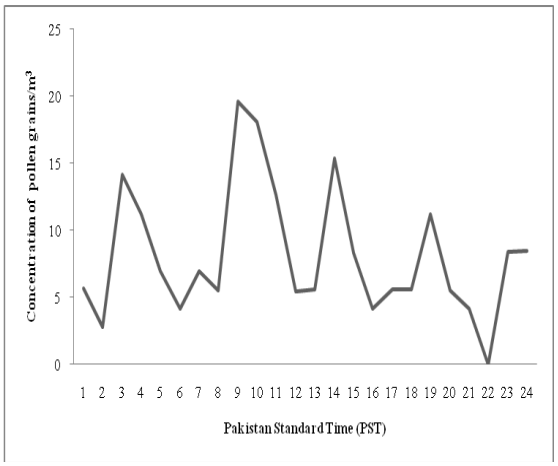

Figure 2. Diurnal pattern of *Cyperus rotundus*

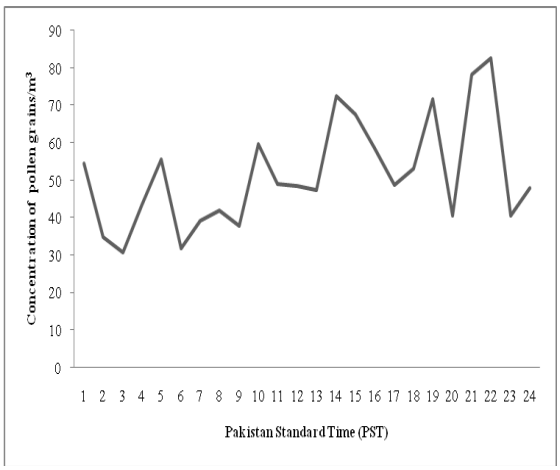

Figure 3. Diurnal pattern of grass

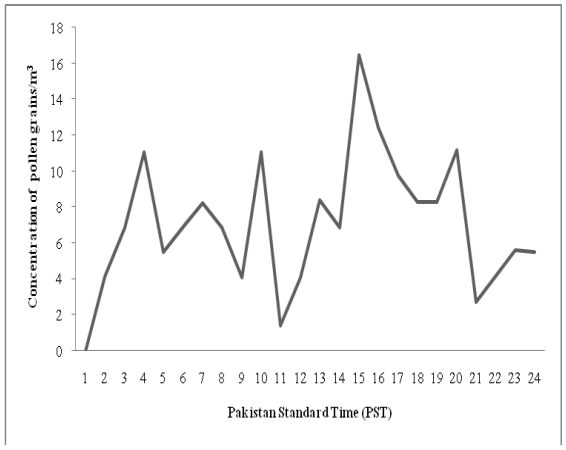

Figure 4. Diurnal pattern of *Prosopis juliflora*

Amaranthaceae/Chenopodiaceae type showed a peek pollen count at 3am (Figure 1); *Cyperus rotundus* showed maximum value at 9 am (Fig. 2); Poaceae or grass pollen type did not show any peak count at a specific time of day (Figure 3), and *Prosopis juliflora* showed highest pollen concentration at 3 pm showing afternoon maxima (Figure 4).

Statistical Analysis

Pearson chi-square test "p-value" was performed by using SPSS software to determine the correlation of meteorological factors with pollen grains count. Average temperature, wind humidity, wind speed, clouds and precipitation (Table 3) were correlated with average monthly pollen count. Correlations were found to be significant when the *p* value was >0.05 or equal to 0.05 (Table 4). Our data revealed that strong positive correlation has been found between Amaranthaceae/Chenopodiaceae pollen grains count and Average wind speed (p=0.05). Significant positive correlation also were observed between *Azadirachta indica* pollen grains count and precipitation (p=0.03). *Betula utilis* pollen grains showed significant positive correlation with humidity (p=0.03). *Brassica campestris* pollen grains showed significant positive correlation with humidity (p=0.01), wind speed (p=0.04), and negative correlation with precipitation (p=-0.04). Asteraceae pollen grains showed a positive correlation with temperature (p= 0.05) and wind speed (p=0.01). *Daucus carota* pollen grains were negatively correlated with humidity (p=-0.02). *Delonix regia* pollen grains were negatively correlated with precipitation (p=-0.04). *Ephedra* sp. pollen grains were negatively correlated with humidity (p=-0.02). *Eucalyptus globulus* pollen grains were negatively correlated with clouds (p=-0.05). *Prosopis juliflora* pollen grains were positively correlated with humidity (p=0.03) and negatively correlated with rain fall (p=-0.01). *Tamarix indica* pollen grains were positively correlated with temperature (p=0.03) and negatively correlated with humidity (p=-0.02). *Thuja orientalis* pollen grains were positively correlated with humidity (p=0.02) and wind speed (p=0.02). *Typha angustifolia* pollen grains were positively correlated with clouds (p=0.05).

Table 3. Climatic data of Karachi

Months	Temperature ºC	Relative Humidity %	Perception mm	Wind speed m/s	Cloud
Aug-09	30.2	76.7	1.4	6.8	5.9
Sep-09	29.6	73.7	68.9	7.3	3.5
Oct-09	30.3	63.7	0	4	0.9
Nov.-2009	24.3	44.6	0	3.6	1.3
Dec-09	20.8	46	0	3.3	1.8
Jan-10	19.9	53.6	0	3.5	1.7
Feb-10	21.3	48.2	0	4.6	1.4
Mar-10	27.2	60.2	0	4.9	1
Apr-10	30.4	62.6	0	6.1	1.5
May-10	30.2	70.2	0	8.1	1.9
Jun-10	31.5	73	3.2	8.2	3.8
Jul-10	30.9	74.7	3.9	7.3	5.5
Yearly Avg.	27.2	62.3	6.5	5.6	2.5

Table 4. Correlation of meteorological data with total pollen count

Pollen types	Avg. Temperature	Avg. Humidity	Avg. Precipitation /Rain Fall	Avg. Wind Speed	Clouds
Amaranthaceae/Chenopodiaceae	0.15	0.18	0.18	0.05	0.15
Azadirachta indica	-0.16	-0.07	0.03	-0.15	-0.16
Betula utilis	0.16	0.03	-0.08	-0.21	-0.21
Brassica campestris	0.06	0.01	-0.04	0.04	0.03
Capparidaceae	0.16	0.28	-0.06	0.15	0.45
Asteraceae	0.05	0.06	0.23	0.01	-0.11
Conocarpus erectus	0.06	0.11	0.00	0.00	0.14
Cyperus rotundus	0.12	0.19	0.31	0.15	0.18
Daucus carota	0.08	-0.02	-0.08	0.10	-0.08
Delonix regia	0.22	0.21	-0.04	0.32	0.17
Ephedra procera	0.13	-0.02	-0.09	-0.06	-0.19
Eucalyptus globulus	0.11	0.07	0.08	0.10	-0.05
Poaceae	0.14	0.18	0.15	0.13	0.20
Guaicum officinale	0.10	0.10	0.04	0.14	0.01
Lucinea leucocephala	-0.17	-0.20	-0.09	-0.06	-0.14
Moringa oleifera	0.16	0.28	-0.06	0.15	0.45
Pinus roxburghii	0.16	0.16	-0.08	0.30	-0.08
Prosopis juliflora	0.11	0.03	-0.01	-0.15	-0.13
Rumex crispus	-0.18	-0.20	-0.09	-0.18	-0.20
Tamarix indica	0.03	-0.02	-0.09	-0.18	-0.18
Thuja orientalis	0.10	0.02	-0.08	0.02	-0.08
Typha angustifolia	0.09	0.06	0.27	0.08	0.05
Total pollen grains	0.48	0.56	0.52	0.28	0.49

DISCUSSION

The atmospheric investigation of airborne pollen is very important and essential for the studies and cures of allergic disorders. Aerobiological monitoring of the atmosphere of Karachi city was initiated in August 2009 and was continued until July 2010. Continuous monitoring of the qualitative and quantitative investigation of airborne pollens was carried out to record the occurrence and frequency of the airborne pollens present in the atmosphere of Karachi.

The blooming season of grasses is throughout the year. Hyde [17] suggested that most of the grasses have regular daily period of anthesis, mostly at 9:00 hours. Very few grasses flower in the morning and late evening.[18] Amaranthaceae/Chenopodiaceae also flower throughout the year like *Amaranthus viridus* flowers all year round. Pollen grains of *Cyperus rotundus* have also been trapped from August 2009 to July 2010 except in December-09, which is also confirmed by its flowering period. *Eucalyptus globulus* flowers from mid winter to mid summers and our spore trap also trapped *Eucalyptus globulus* pollen grains in almost similar months. *Guaicum officinale* is an ornamental tree which is planted throughout the city along the road sides and parks. This tree also flowers from March-October and in our study year the pollen grains were captured from February to October and few pollen grains in December. *Prosopis juliflora* flowers twice a year i.e. March- June, September-November and its highest pollen grain concentration was recorded in the month of October 2009. *Tamarix indica* blooming season is from January-October and our sampler also recorded the highest concentration of pollen grains of *Tamarix indica* in the month of October 2009.

During the survey in the atmosphere of Karachi city, a total of 22 pollen types have been reported, among them, 11 pollen types are reported to be allergenic by various workers. Among these the grass pollen grains are the most abundant around 42.51% (1242 pollen grains/m^3) of the total pollen counts. Grass pollen grains are detected in almost all of the

aerobiological studies throughout the world. Over the world, 40% of allergic patients are sensitive to grass pollen allergy.[19,20] The other pollen types which have been recorded from the city of Karachi in a concentration more than 5% like Amaranthaceae/Chenopodiaceae 32.44% (948 grains/m^3), *Cyperus rotundus* 6.67% (195 grains/m^3) and *Prosopis juliflora* 5.78% (169 grains/m^3) have also been recognized as allergenic pollen producing plants.[21-24] Furthermore, the pollen types with known allergenicity, but found in lower concentration during the study period, are *Brassica campestris* 2.05% (60 grains/m^3),[25,26] *Tamarix* sp. 1.06% (31 grains/m^3),[27] *Eucalyptus globules* 0.86%(25 grains/m^3),[28] *Thuja orientalis* 0.31% (9 grains/m^3),[27] *Azadirachta indica* 0.27% (8 grains/m^3),[29] *Moringa oleifera* 0.21% (6 grains/m^3),[26] *Betula utilis* 0.03%(1 grains/m^3)[30] (Table 2). Threshold value for any plant pollen to induce an allergenic reaction varies with the type of pollen. According to the studies for grass pollen this value is more than 30 pollen grains/m^3, but for *Ambrosia* sp. pollen (Asteraceae), the value is around 10-15 pollen grains/m^3.[31,32]

In the survey, the highest pollen amounts have been recorded during August-October. The most significant time of the year for allergenic pollen collection is August 2009 to October 2009. The same pattern of high incidence of pollen count in the months of August to October has also been reported by Chauhan and Goyal.[33] The peaks of pollen grain concentration in various months have been compared to the allergy symptoms reported in Karachi.[34] According to a survey published about some common epidemics in Karachi city, the month of August has the highest patients suffering from allergy. Similarly in our study the highest count of pollen grains are observed in August, due to grass pollens.

The results obtained in the present work have shown highest concentration of airborne pollen grains was found in Karachi have been produced by trees, shrubs, and herbs. Woody taxa (trees) has contributed to the major pollen grain types in our studied data but the highest number of pollen grains during the study period August 2009- July 2010 has been contributed by the herbaceous taxa specially Poaceae (Grass pollen grains). Pollen grains belonging to *Betula utilis*, Capparidaceae, Compositae, *Delonix regia*, *Moringa oleifera*, *Pinus roxburghii*, *Rumex crispus*, are observed in very low concentrations.

The present volumetric survey of airborne pollen has not only contributed to the updated information of airborne pollen in Karachi but also first time presented the correlation with meteorological factors. High pollen grain concentration of grasses and weeds was detected in the city of Karachi which is alarming as the plants are classified as highly allergenic pollen producing plants. It is hoped that the data presented in this one year survey of Karachi will help the physicians of this region to properly diagnose the allergy causing agents.

ACKNOWLEDGEMENTS

We are highly thankful to Higher Education Commission Islamabad for funding the project entitled "Identification and quantification of allergenic pollen from Sindh". We are also thankful to the Pakistan Meteorological Department, Karachi for providing the climatic data of Karachi city.

REFERENCES

1. D'Amato G, Cecchi L, Bonini S, Nunes C, Annesi-Maesano I, Behrend H, et al. Allergenic pollen and pollen allergy in Europe. Allergy 2007; 62(9):976-90.
2. Mandal J, Chakraborty P, Roy I, Chatterjee S, and Gupta-Bhattacharya S. Prevalence of allergenic pollen grains in the aerosol of the city of Calcutta, India: A two year study. Aerobiologia 2008; 24:151-64.
3. Ciprandi G, Tosca MA, Marseglia GL, Klersy C. Relationships between allergic inflammation and nasal airflow in children with seasonal allergic rhinitis. Ann Allergy Asthma Immunol 2005; 94(2):258-61.
4. D'Amato G[1], Spieksma FT, Liccardi G, Jäger S, Russo M, Kontou-Fili K, et al. Pollen related allergy in Europe. Allergy 1998; 53(6):567-78.
5. Puc M, Wolski T. *Betula* and *Populus* pollen counts and meteorological conditions in Szczecin, Poland. Ann Agric Environ Med 2002; 9(1):65-9.
6. Bianchi MM, Olabuenaga SE. A 3-year airborne pollen and fungal spores record in San Carlos de Bariloche, Patagonia, Argentina. Aerobiologia 2006; 22:247-57.
7. Beggs PJ. Adaptation to impacts of climate change on aeroallergens and allergic respiratory diseases. Int J Environ Res Publ Health 2010; 7(8):3006-21.
8. Chapman JA, Williams S. Aeroallergens of the Southeast Missouri area, a report of skin test frequencies and air sampling data. Ann Allergy 1984; 52(6):411-7.

9. Ricketti AJ Allergic rhinitis. In Patterson R, editors). Allergic diseases: Diagnosis and management (4th ed.). JB Lippincott, Philadelphia; 1993:225–53,
10. Erkara IP, Cingi C, Ayranci U, Gurbuz KM, Pehlivan S, Tokur S. Skin prick test reactivity in allergic rhinitis patients to airborne pollens. Environ Monit Assess 2009; 151(1-4):401-12.
11. Kazmi S, Qaiser M, Ali SI. A preliminary study of airborne pollen grains in Karachi. Pak J Bot 1984; 16(1) 65-74.
12. Perveen A, Qaiser M, Sad-ul-Islam M. Airborne pollen survey of Karachi and adjacent areas in relation to allergy. World Appl Sci J 2007; 2:289-98.
13. Waqar MA, Hasnain SM, Khan M. Airborne pollen survey in Karachi: A coastal city in Sindh Province of Pakistan. Ind J Aerobio 2010; 23:7-17.
14. Anonymous. Airborne pollens and spores: A guide to trapping and counting. British Aerobiology Federation, Aylesford 1995.
15. Smith EG. Sampling and Identifying Allergenic Pollens and Molds. An illustrated identification manual for air samplers. Blewstone Press, San Antonio 1990.
16. Nayar TS. Pollen Flora of Maharashtra State, India. Jawahar Offset Press, New Delhi 1990.
17. Hyde HA. Grass pollen in Great Britin. Acta Allergol 1952; 5(2):98-112.
18. Hyde HA, Williams, DA. Dirurnal variation in the incidence of grass pollen. New Phytol 1945; 44(1):83-94.
19. Freidhoff LR, Ehrlich-Kautzky E, Grant JH, Meyers DA, Marsh DG. Study of the human immune response to Lolium perenne (rye) pollen and its components, Lol p I and Lol p II (rye I and rye II). I. Prevalence of reactivity to the allergens and correlations among skin test, IgE antibody, and IgG antibody data. J Allergy Clin Immunol 1986; 78(6):1190-201.
20. Andersson K, Lidholm J. Characteristics and immunobiology of grass pollen allergens. Int Arch Allergy Immunol 2003; 130(2):87-107.
21. Singh AB, Kumar P. Common environmental allergens causing respiratory allergy in India. Indian J Pediatr 2002; 69(3):245-50.
22. Boral D, Chatterjee S, Bhattacharya K. The occurrence and allergising potential of airborne pollen in west Bengal, India. Ann Agric Environ Med 2004; 11(1):45-52.
23. Killian S, McMichael J. The human allergens of mesquite (*Prosopis juliflora*). Clin Mol Allergy 2004; 2(1):8.
24. Waqar MA, Khan M, Saleem A, Hasnain SM. Possible effects of cultivated plants in the development of allergy in population of Sindh, Pakistan. J Chem Soc Pak 2010; 32(1):95-100.
25. Singh BP1, Verma J, Rai D, Sridhara S, Gaur SN, Gangal SV. Immunobiochemical characterization of Brassica campestris pollen allergen. Int Arch Allergy Immunol 1995; 108(1):43-8.
26. Bhattacharya P (Sasmal), Pal JK. Scope of research on pollen grains in Arambagh region of Hooghly District (India) with reference to allergic disorders. Int J Curr Sci 2013; 8:E09-15
27. Carinanos P, Casares-Porcel, M. Urban green zones and related pollen allergy: A review. Some guidelines for designing spaces with low allergy impact. Landsc Urban Plan 2011; 101:205-14.
28. Galdi E, Perfetti L, Calcagno G, Marcotulli MC, Moscato G. Exacerbation of asthma related to Eucalyptus pollens and to herb infusion containing Eucalyptus. Monaldi Arch Chest Dis 2003; 59(3):220-1.
29. Karmakar PR, Chatterjee BP. Isolation and characterization of two IgE-reactive proteins from Azadirachta indica pollen. Mol Cell Biochem 1994; 131(1):87-96.
30. Bist A, Kumar L, Roy I, Ravindran P, Gaurs SN, Singh AB. Clinico-immunologic evaluation of allergy to Himalayan tree pollen in atopic subjects in India--a new record. Asian Pac J Allergy Immunol 2005; 23(2-3):69-78.
31. Bergmann K, Zuberbier T, Augustin J, Mücke H, Straff W. Climate change and pollen allergy: cities and municipalities should take people suffering from pollen allergy into account when planting in public spaces. Allergo J 2012; 21(2):103-7.
32. Kiotseridis H, Cilio CM, Bjermer L, Tunsäter A, Jacobsson H, Dahl Å. Grass pollen allergy in children and adolescents-symptoms, health related quality of life and the value of pollen prognosis. Clin Transl Allergy 2013; 3:19-30.
33. Chauhan SVS, Goyal R. Pollen calendar of Agra city with special reference to allergenic significance. J Environ Biol 2006; 27: 275-81.
34. Rao, TA, Siddiqui BA, Shaikh MA, Ahmed M, Shaikh AH, Ahmed F. Dynamics of some common epidemics in Karachi, Pakistan. J Pak Med Assoc 2011; 61(11): 1072-9.